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Preliminary Summary of Geology and Groundwater Resources in the Klondike Area, Grand County, Utah

Letter Report

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M O A B P R O J E C T

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Introduction

The U.S. Department of Energy (DOE) is preparing a plan to dispose of uranium mill tailings currently located at the former Atlas Minerals Company mill about 3 miles northwest of Moab, Utah. An area about 20 miles northwest of Moab, called the Klondike Area, is being investigated as a possible site for an engineered repository for relocation of the tailings. The Klondike Area is located in the northernmost portion of the Paradox Basin on the Colorado Plateau (Figure 1).

Attributes of this site are its relative proximity to the Moab tailings site, its remoteness from population centers, the presence of a thick section of shale to minimize leakage of contaminants into underlying groundwater aquifers, and its tectonic stability. The Klondike Area, for the purpose of this report, is defined as the area highlighted in Figure 1 and shown on Figure 2. This report provides a summary of the stratigraphy, structure, and water resources of this area to help provide a basis to assess the suitability of the area for siting a repository. Additional geologic and hydrogeologic characterization would be conducted prior to a decision to relocate tailings to the Klondike Area.

Geology

Sources of Information—The Utah Geological Survey conducted extensive geologic mapping in the Klondike Area (Doelling 1997; Doelling 2000; and Doelling 2001). In particular, map features of the Valley City quadrangle by Doelling (1997) are used in the discussions that follow. In addition to the information contained in the Utah Geological Survey reports, borehole logs, geologic cross sections, seismic data, and geologic reports were obtained from the Anaconda Collection housed in the American Heritage Center, University of Wyoming, Laramie, Wyoming. Mineral exploration data are usually proprietary but the Anaconda Company was disbanded and its files were made available to the American Heritage Center. The American Heritage Center accepted the collection with the condition that fees would be charged to sustain it.

Data in the Anaconda Collection were collected during an extensive subsurface uranium exploration program conducted by Anaconda Company geologists from 1975 to 1980. During this period, the Anaconda Company drilled and geophysically logged 28 exploration borings in the Klondike Area (Table 1; locations shown in Figure 2). Fifteen of the Anaconda borings were drilled in the Courthouse Syncline north of Canyonlands Airport and penetrated from the Mancos Shale to the Entrada Formation or Navajo Sandstone. The other Anaconda wells penetrated various sections in the surrounding portion of the Klondike Area and terminated in the Moenkopi or Cutler Formations. Data for 14 oil and gas exploration wells in the Klondike Area were obtained from the Utah Division of Oil, Gas, and Mining, Salt Lake City, Utah. Heylmun et al. (1965) provided additional subsurface data. Unlike mineral exploration data, oil and gas records are available to the public.

Table 1. Formation Tops as Determined by Correlating Geophysical Logs[a]
(feet below ground surface; refer to Figure 3 for geologic units)

Designation	Boring	Elev (ft)	Total Depth (ft)	Stratigraphic Unit (ft)							
				Kdcm	Jmb	Jmst	Js	Jem	Jes	Jed	Jn
Anaconda Mineral Tests											
021–1	2420–21–1	4604	1165								Surf[b]
023–1	2419–23–1	4847	1800						Surf	212	330
09–1	2419–9–1	4716	2050			Surf		95	170	460	600
10–1	2419–10–1		1967				Surf	26	119	400	489
14–1	2319–14–1	4680	2260	700	850	1030	1210	1300	1390	1660	1775
14–2	2419–14–2	4709	1868						Surf	192	290
16–1	2319–16–1	4553	2445	1025	1110	1430	1560	1675	1745	2050	2150
16–2A	2319–16–2A	4581	1804	980	1122	1390	1605	1700	1755		
17–1	2319–17–1	4523	2483	870	1070	1305	1535	1642	1710	2040	2140
18–1	2319–18–1	4496	2363	612	760	960	1110	1250	1350	1650	1780
20–1	2420–20–1	4596	1540						Surf		
21–1	2319–21–1	4514	2060	870			1250	1410	1500	1760	1900
22–1	2419–22–1	4778	1788							90	214
23–1	2319–23–1	4586	2343	780	900	1140	1320	1420	1510	1800	1900
24–1	2318–24–1	4474	754		Surf	252	480	520	590		
24–2A	2318–24–2A	4477	772		Surf	160	420	460	540		
4–1	2319–4–1	4625	2135					168	260	537	700
9–1	2319–9–1	4540	2494	1012	1155	1440	1590	1720	1790	2090	2190
9–2	2319–9–2	4530	1798	990	1140	1320	1550	1685	1750		
9–3	2319–9–3	4543									
9–4	2319–9–4	4565	1808	1010	1160	1440	1580	1700	1770		
9–5	2319–9–5	4552	1804	1000	1160	1420	1585	1705	1780		
9–6	2319–9–6	4550	1805	1010	1155	1410	1590	1700	1780		
AM–22	AM–22	4640	3325	Surf							
AT–1	AT–1	4512	2698		900			1450	1520	1800	1962
AT–2	AT–2	4430	2364				Surf	48	95	406	534
AT–3	AT–3	4570	2652	940	1075	1295	1500	1650	1710	2030	2126
BW–1	BW–1	4732	2980	Surf				715			
Oil and Gas Wells											
CGH	Continental Govt Hall	4834	2785			Surf		150	250	500	630
CSV	Continental Salt Valley	4684	13223	900	1297					2235	
EQ–D	Equity Donohue	4515	6618	800	1050	1400		1600	1750	2000	2100
EQ–S	Equity No. 1 State	4600	7290	470	610	820	1000	1205	1305	1610	1740
HIL	Hilliard Klondike 1	4459	5282	Surf			355	400	498	770	912
K1S	Kimball No. 1 State	4919	1215	675	715						
KMS	Kimball No. 1 Mtn State	4925	1190	682	1053						
MA	Menoir Aubrey	4654	4910	1270	1470	1620	1760	2040	2180	2410	2518
MBO–1	Moab Oil No. 1	4800	700		Bottom						
MF–2	Mnt Fuel Klondike 2		4766						Surf		90
MF–3	Mnt Fuel Klondike 3	4900	2650			Surf		295	370	654	790

[a]Geophysical data from the American Heritage Center and the Utah Oil, Gas, and Mining Division files.
[b]Surf = at ground surface.

Table 1 (continued). Formation Tops as Determined by Correlating Geophysical Logs[a]
(feet below ground surface; refer to Figure 3 for geologic units)

Designation	Boring	Elev (ft)	Total Depth (ft)	Stratigraphic Unit (ft)							
				Kdcm	Jmb	Jmst	Js	Jem	Jes	Jed	Jn
Oil and Gas Wells											
QW	Hagen Queen No. 1 Well	4800	920	410							
SMF	Shell 1–21 Mtn Fuel	4525	10333			Surf	32	183	300	590	722
Tex	Texaco Govt McKinnon	4589	12083	1000	1100	1300	1500	1600	1680	1972	2070

[a]Geophysical data from the American Heritage Center and the Utah Oil, Gas, and Mining Division files.

Structure: The Colorado Plateau is a regional tectonic block that has remained less deformed than the surrounding mountain and basin-and-range terrains. Within the Colorado Plateau Province, a large expanse of evaporites was deposited in the Paradox Basin (Figure 1) during the Pennsylvanian Period. The salt deposited with these evaporites has risen, because of its low density, and caused the formation of a series of northwest trending salt anticlines. Much of the geologic structure in the Klondike Area results from the upwelling of the salt in the Paradox Formation along the Salt Valley and Moab salt anticlines.

The geologic structure of the Klondike Area is dominated by the northwest trending and plunging Courthouse Syncline (Figure 2). The Courthouse Syncline is expressed as a broad expanse of Mancos Shale with beds on both flanks dipping gently toward the synclinal axis. Uplift along the Salt Valley Anticline to the northwest has severely deformed the surrounding geologic formations and caused dramatic erosional unconformities. Doelling [1997 (Plate 2)] estimates that more than 6,000 feet of Pennsylvanian through Triassic strata present in the middle of the Courthouse Syncline is completely missing because of an angular unconformity 5 miles to the northeast on the southwest flank of the Salt Valley Anticline. The Moab Salt Anticline is well defined from surface exposures extending from the southernmost portion of the Klondike Area southeast to near the City of Moab. In the Klondike Area, the Moab Anticline is offset from the main trend of the anticline by a set of "horsetail" faults shown near borings 20-1 and 23-1 on Figure 2. There is little surface exposure of the Moab Anticline in the Klondike Area, but the presence of a salt core is defined by gravity and seismic data (Figure 4).

The Moab fault, a dominant northwest striking normal fault, is conspicuous from the southeast corner of the Klondike Area nearly to the City of Moab. In the vicinity of the southeast corner of the Klondike Area, the Moab fault is displaced to the west by a series of horsetail faults. Doelling (1997 and 2000) estimates that the stratigraphic displacement on the Moab fault exceeds 3,500 feet in Moab Canyon (about 5 miles southeast of the Klondike Area), decreases to about 1,200 feet near boring 21-1, and is less than a few hundred feet in the Blue Hills Area (an area approximately between borings 10-1 and 24-1, Figure 2).

Stratigraphy: Rocks exposed in the Klondike Area range in age from the Pennsylvanian Paradox Formation to the Cretaceous Mancos Shale (Figure 2). Bedrock is well exposed throughout most of the area but is covered by a thin veneer of Quaternary sediments in some places. Mancos Shale outcrops in the Courthouse Syncline define an area most amenable to the siting of a mill tailings repository. The upper part of the stratigraphic section (Navajo Sandstone and younger formations) is shown on cross sections A-A′ and B-B′ (Figures 5 and 6). An example of the geophysical logs used to create the cross sections and a stratigraphic column are on Figure 3. The deeper stratigraphic section is best known from the lithology encountered in the Texaco Government McKinnon No. 1 oil test (Texaco test) that was completed to 12,083 feet.

Deep Stratigraphy—On the basis of data collected from surrounding areas, the Klondike Area is probably underlain by (in ascending order) Precambrian metamorphic and igneous rocks, Cambrian well-indurated sedimentary rocks, and Devonian limestone and sandstone (Doelling 1997; Hite and Lohman 1973). The Texaco test bottomed in Mississippian rocks dominated by marine limestone that overlies the Devonian rocks (Table 2). The Pennsylvanian Paradox Formation overlies Mississippian rocks and varies in thickness from about 800 to 11,800 feet in the area because of salt flowage (Doelling 1997). The Paradox Formation, consisting of clastic sediment and limestone interbedded with gypsum and halite, is about 1,425 feet thick in the Texaco test (Table 2). Marine limestones of the Pennsylvanian Honaker Trail Formation overlie the Paradox Formation and are 2,300 feet thick in the Texaco test. The oldest formation dominated by clastic sediments is the Permian Cutler Formation that overlies the Honaker Trail and is 2,100 feet thick in the Texaco test. Several of the oil tests in the Klondike Area penetrated a white sandstone unit that may correlate with the White Rim Sandstone Member of the Cutler Formation. The White Rim Sandstone is reported as 138 feet thick in the Mountain Fuel Klondike No. 3 test (Utah Division of Oil, Gas, and Mining records). The Triassic Moenkopi Formation, consisting largely of siltstone and shale, overlies the Cutler Formation and is 1,207 feet thick in the Texaco test (Table 2). The Triassic Chinle Formation is dominated by fluvial sandstone and siltstone and overlies the Moenkopi Formation. The Chinle Formation, including the basal coarse sandstones in the Shinarump Member, is 718 feet thick in the Texaco test. The eolian sandstone of the Jurassic Wingate Sandstone and the finer-grained fluvial Jurassic Kayenta Formation overlie the Chinle Formation.

Table 2. Depths to Tops of Geologic Units and Thicknesses in the Deep Portion of the Texaco Government McKinnon No. 1 Oil Test

Geologic Unit	Depth to Top of Unit (ft)	Reference
Kayenta Formation	2,700	[a]Doelling 1997
Wingate Formation	3,000	[a]Doelling 1997
Chinle Formation	3,475	[b]UDOGM
Shinarump Member	4,090	[b]UDOGM
Moenkopi Formation	4,193	[b]UDOGM
Cutler Formation	5,400	[a]Doelling 1997
Hermosa Formation	7,500	[a]Doelling 1997
Paradox Formation	9,800	[a]Doelling 1997
Mississippian rocks	11,474	[b]UDOGM

[a]Estimated from a cross section in Doelling 1997.
[b]UDOGM = Utah Division of Oil, Gas, and Mining.

Shallow Stratigraphy—The Jurassic Navajo Sandstone forms predominant cliffs and erosion-resistant hills in the Klondike Area. It is composed of eolian sandstone that is often bleached white and varies in thickness from about 300 to 700 feet (Doelling 1997). The Navajo Sandstone is thicker in the synclines than over the salt anticlines. The top of the Navajo is 2,070 feet below ground surface at the Texaco test in the center of the Courthouse Syncline (Figures 5 and 6; Table 1).

The Jurassic Entrada Formation consists of three members, in ascending order: Dewey Bridge, Slick Rock, and Moab (Figure 3). The Dewey Bridge is composed of sandstone but is finer grained and less resistant than the underlying Navajo Sandstone or overlying Slick Rock Member. The Slick Rock Member is a massive cliff-forming sandstone that is well exposed in the western portion of the Klondike Area (Figure 2). The Moab Member (sometimes referred to as the Moab Tongue) is a bleached, massive, cliff-forming sandstone, about 70 feet thick. The Moab Member is well exposed on the southwest flank of the Salt Valley Anticline where it is highly jointed. The Moab Member contains high-grade uranium mineralization (up to 0.5 percent), elevated concentrations of vanadium and chromium, and petroleum smears in Anaconda borings 9-1 through 9-6 and 16-1 (data from the American Heritage Center). The Moab Member has a low, smooth, gamma-ray signal (except where it has high concentrations of uranium daughter products) that is easily identified on gamma ray logs; it was used as a key marker bed to correlate the geophysical logs.

The Jurassic Summerville Formation and the Tidwell Member of the Jurassic Morrison Formation comprise a slope-forming unit of siltstone, sandstone, and shale between the Moab Member of the Entrada Formation and the Salt Wash Member of the Morrison Formation. The overlying Salt Wash Member is composed of about 200 feet of fluvial sandstones and interbedded siltstone and shale. Uranium ores were produced from a large number of mines in the Salt Wash Member. The overlying Brushy Basin Member is composed of about 250 feet of bentonitic shale with occasional interbedded sandstone and siltstone. The Cretaceous Dakota Sandstone and Cedar Mountain Formation overlie the Brushy Basin Member and consist of sandstone and conglomerate interbedded with lesser siltstone. They are often well indurated and form prominent cliffs just below the Mancos Shale.

The Cretaceous Mancos Shale is dominated by thick beds of gray marine shale. It forms low hills over much of the Courthouse Syncline (Figure 2), extending north to the Book Cliffs and east to Grand Junction, Colorado. Regionally, it is up to 3,600 feet thick (Doelling 1997) but only the lower portion is present in the Klondike Area. The Mancos Shale is about 1,000 feet thick in the Texaco test in the center of the Courthouse Syncline. It thins on the northeast and southwest flanks of the Courthouse Syncline. It thickens northwest because of the plunge of the syncline (Figure 7). The Ferron Sandstone Member consists of a relatively thin set of resistant sandstone beds that form a double cuesta along the flanks of the Courthouse Syncline about 200 feet above the base of the Mancos Shale.

Water Resources

Few data exist to evaluate the water resources in the Klondike Area. Possible water bearing units are discussed in order of ascending age starting with the Navajo Sandstone. Locally, precipitation recharges an area of bedrock sandstone aquifers exposed on the west flank of the Salt Valley Anticline. The water flows through the sandstones beneath the Courthouse Syncline. Jointing because of uplift of the Salt Valley Anticline, seen particularly well in exposures of the Moab Member, afford conduits to increase the infiltration and transport of the groundwater. Recharge to the bedrock sandstone aquifers also occurs over vast areas of outcrops in the region.

Navajo Sandstone: Numerous springs including Lower Courthouse Spring (Figure 8) flow from the Navajo Sandstone. Flux from these springs is limited to less than 10 gallons per minute (gpm) but is sufficient to water a few cattle (Doelling 2000). Observations by Anaconda personnel during mineral drilling suggest that the Navajo Sandstone is a major water-bearing unit beneath the Courthouse Syncline in the Klondike Area. The Navajo Sandstone is likely the most beneficial water supply beneath the area being investigated as a uranium mill tailings repository site.

A water well (Airport Well No. 1, Figure 8) was drilled at the Canyonlands Airport in 1996 (Utah Division of Water Rights website). The well was drilled to a depth of 1200 feet, but the depth of the well screen is unknown. A crude drillers log lists white, orange, and red sandstone from 955 to 1200 feet. The stratigraphy as defined in cross section B–B′ (Figure 6) indicates that this well is probably completed in the Navajo Sandstone. The static water level was at 85 feet below ground surface.

Records from the Utah Division of Water Rights website indicate locations of four water wells that were drilled on state sections in the vicinity of the Dalton Wells (Figure 8). No other information is provided in the files. A preliminary field check indicates that these wells are providing water for crop irrigation. Drilling equipment on the site indicated that this water resource was still being developed in March 2002. Judging by the large size of the drilling equipment, the target is likely a deep bedrock aquifer, perhaps the Navajo Sandstone. The owner/driller was not available during the preliminary field visit.

Groundwater in the Navajo Sandstone is good quality with total dissolved solids typically less than 220 milligrams per liter (mg/L) (Doelling 2000, after Blanchard 1990). The Navajo Sandstone is the most important source of drinking water in the Moab Valley about 20 miles southeast of the Klondike Area (Eisinger and Lowe 1999). Wells produce in excess of 1,000 gpm of high quality water from the Navajo Sandstone for Moab’s water supply (Sumison 1971).

Jobin [1962 (in Blanchard 1990)] estimated a range from 0.4 to 1 feet per day (ft/day) for hydraulic conductivity, and from near 0 to 700 square feet per day (feet^2/day) for the transmissivity of the Navajo Sandstone. Specific capacities of two water-supply wells at the entrance to Arches National Park completed in the Navajo Sandstone were 1.7 and 14.5 gallons per minute per foot (Blanchard 1990).

Entrada Formation: Groundwater in the Entrada Formation is generally good quality with total dissolved solids typically less than 220 mg/L (Doelling 2000, after Blanchard 1990). No well data are available locally to determine the water resource potential of the Entrada Formation in the Klondike Area. Water from Brink Spring (Figure 8) that discharges from the Entrada Formation along the Moab fault is good quality; a total dissolved solids concentration of 119 mg/L was measured in 1985 (Blanchard 1990). Groundwater sampled from the Entrada Formation in a well about 1 mile south of the Klondike Area (sec. 17, T. 24 S., R. 19 E.) has a total dissolved solids concentration of 300 mg/L (Blanchard 1990). In the deep subsurface, the Entrada Formation contains much higher concentrations of salts. In 9 deep (depths of 900 to 5,300 feet) wells located north of Interstate Highway 70 between Crescent Junction and Cisco, Utah, total dissolved solids in the Entrada Formation range from 9,470 to 104,000 mg/L (Blanchard 1990 after Feltis 1966 and unpublished U.S. Geological Survey data). One of these wells is about 5 miles north of the Klondike Area at Crescent Junction; the total dissolved solids concentration in the Entrada Formation in this well is 10,300 mg/L at 1,750 feet. Jobin [1962 (in Blanchard 1990)] estimated a range of 0.1 to 1.1 ft/day for hydraulic conductivity and 50 to 150 ft^2/day for the transmissivity of the Entrada Formation.

Morrison Formation: On the basis of depths estimated from cross section A–A′ (Figure 5), the salt water sampled at 600 and 870 feet (Utah Oil, Gas, and Mining Division well files) in the Hagen Queen No. 1 is probably from the Salt Wash Member of the Morrison Formation (Figure 8). A well about 5 miles south of Cisco (sec. 29, T. 22 S., R. 23 E.) flows from the Brushy Basin Member and had a total dissolved solids concentration of 1,020 mg/L in 1985 (Blanchard 1990). In six deep wells (depths of 400 to 2,500 feet in depth) north of Interstate Highway 70 between Crescent Junction and Cisco, total dissolved solids in the Morrison Formation ranged from 4,830 to 25,700 mg/L (Blanchard 1990, after Feltis 1966; unpublished U.S. Geological Survey data). One of these wells is about 5 miles north of the Klondike Area, at Crescent Junction; the total dissolved solids concentration in the Morrison Formation in this well is 13,900 mg/L at a depth of 1,150 feet.

On the basis of data provided by Gwynn (1996), groundwater quality in the Morrison Formation appears to be highly variable. Groundwater in a well near Cisco, Utah (the well closest to the Klondike Area with data reported by Gwynn,1996), has a total dissolved solids concentration of 16,624 mg/L.

Dakota Sandstone and Cedar Mountain Formation: The Hagen Queen No. 1 well is on the west flank of the Courthouse Syncline (Figure 8). This well was drilled as an oil test, was abandoned in 1913, and was later converted to a water well (Doelling 1997). According to information in the Utah Oil, Gas, and Mining Division well files, fresh water was encountered at 425 feet and salt water at 600 feet and 870 feet. Drilling was discontinued at 920 feet. On the basis of depths estimated from cross section A–A′ (Figure 5), the shallower groundwater is probably in the Dakota Sandstone or Cedar Mountain Formation.

The Utah Division of Water Rights website lists the location of a second well (called Airport Well No. 2 on Figure 8) at Canyonlands Airport but provides no information about the well. An airport employee believes the well that supplies water to the airport is completed in the Dakota Sandstone. A preliminary ground check indicated that the well mentioned by this employee may be Airport Well No. 2.

No data were available to assess the quality of groundwater in the Dakota Sandstone or Cedar Mountain Formation in the Klondike Area. Water in this formation is commonly of poor quality because the sandstone beds are just below the Mancos Shale. A high concentration of salt in the Mancos Shale often produces high concentrations of salt in irrigation runoff. Carbonaceous beds in the Dakota Sandstone may contribute metals and additional salt to groundwater. A sample of groundwater collected from a flowing well completed in the Dakota Sandstone or Cedar Mountain Formation about 6 miles south of Cisco (sec. 25, T. 22 S., R. 23 E.) had a total dissolved solids concentration of 1,190 mg/L in 1985 (Blanchard 1990). A spring on the east flank of the Salt Valley Anticline about 4 miles east of the Klondike Area (Sec. 32, T. 22 S., R. 21 E.) discharging from the Dakota Sandstone or Cedar Mountain Formation had a total dissolved solids concentration of 1,020 mg/L in 1985 (Blanchard 1990).

A well was drilled to 458 feet in 1964 near the microwave tower, adjacent to U.S. Highway 191, on the east side of the Courthouse Syncline (MIC–1 on Figure 8). The shallow depth suggests that this well was completed in the Dakota Sandstone or Cedar Mountain Formation. Three drawdown tests indicate a drawdown of about 200 feet when pumped at about 3 gpm for 3 to 4 hours.

Mancos Shale: A well was drilled in 1994 by the Grand County Solid Waste Management in the vicinity of the landfill in the Courthouse Syncline (Utah Division of Water Rights website). The well is shown on Figure 8 as "Landfill No. 1". The well was drilled to 500 feet and bottomed in the lowermost part of the Mancos Shale. This hole was dry and was abandoned.

The Ferron Sandstone Member is probably not a water-bearing unit. During drilling of the Anaconda borings, most or all of the Mancos Shale was drilled dry, indicating that little water was present. Blanchard (1990) in a study of water resources in all of Grand County, Utah, including the Klondike Area, concluded that the Mancos Shale does not yield groundwater and that it forms an aquiclude that inhibits groundwater migration to deeper stratigraphic units.

Uppermost Aquifer Underlying the Mancos Shale in the Courthouse Syncline: The uppermost aquifer that contains groundwater having a beneficial use is of importance when siting a disposal cell. The Dakota Sandstone and Cedar Mountain Formation may contain groundwater, but additional work is required to determine if it is a usable aquifer.

Aquifers below the Dakota Sandstone and Cedar Mountain Formation are protected by an additional several hundred feet of Brushy Basin Member between the aquifers and the ground surface. The Brushy Basin Member is composed largely of bentonitic shale that has a tendency to seal itself if it becomes fractured. The next aquifer below the Dakota Sandstone and Cedar Mountain Formation is the Salt Wash Member of the Morrison. This horizon is composed of lenticular fluvial sandstone deposits interbedded with siltstone and shale. The Salt Wash Member is not recognized as a regional aquifer and probably has limited production compared to eolian sandstone units lying below it. The Salt Wash Member is a host for uranium deposits in the Klondike Area; no data were available to evaluate local groundwater quality in the Salt Wash Member.

Regional sandstones with high potential for groundwater production are present below the Salt Wash Member. The Entrada Formation, containing sandstones of the Moab Member and the Slick Rock Member, has high potential for containing usable groundwater. The Moab Member contains ore-grade uranium concentrations and petroleum shows. The Navajo Sandstone is a major groundwater resource throughout the region.

Land Status

During this study, a check of the land status for mining claims and mineral leases in the Klondike Area was made at the U.S. Bureau of Land Management Office in Moab, Utah (Figure 9). Some land on the flanks of the Courthouse Syncline is leased for potassium or oil and gas. A small block of mining claims is present on the southwest flank of the Salt Valley Anticline.

Recommendations

This study was intended to formulate a preliminary conceptual foundation for assessing the Klondike Area as a possible site for a uranium mill tailings repository. Many aspects of the current study were given only a cursory examination. The following recommendations would enhance this study and provide more confidence in future planning of a repository in the Klondike Area:

- Determine depths, screened intervals, and water quality of water wells at the Canyonlands Airport, and irrigation wells near Dalton Wells (Bob Beeman lease).
- Determine if Hagen Queen No. 1 Well still exists. Locate U.S. Geological Survey Bulletin 541 for more information on this well.
- Determine water quality and flux from Klondike Area springs.
- Determine the source of water at the residence on the hill southeast of Crescent Junction.
- Survey to determine definitive locations of existing wells.
- Determine the hydrostratigraphic nature of the Dakota Sandstone, Cedar Mountain Formation, and Mancos Shale by measuring stratigraphic sections and describing bedding features in and near the Klondike Area.
- If there is a desire to site a repository farther north where the Mancos Shale thickens, additional logs of oil and gas borings should be obtained from the Utah Oil, Gas, and Mining Division files. A number of oil and gas wells have been drilled near Crescent Junction.
- Use aerial photos to help locate faults and other geologic features.
- More accuracy can be achieved by integrating the geologic information into a geographic information system. The geologic base map used in this report was from a 1:100,000 scale geologic map (Doelling 2001); more accurate analysis could be obtained using the larger-scale 7.5 minute Valley City (Doelling 1997) and Merrimac Butte (Doelling 2000) geologic quadrangles.
- Additional land status surveys should be conducted.
- Investigate regional tectonism.

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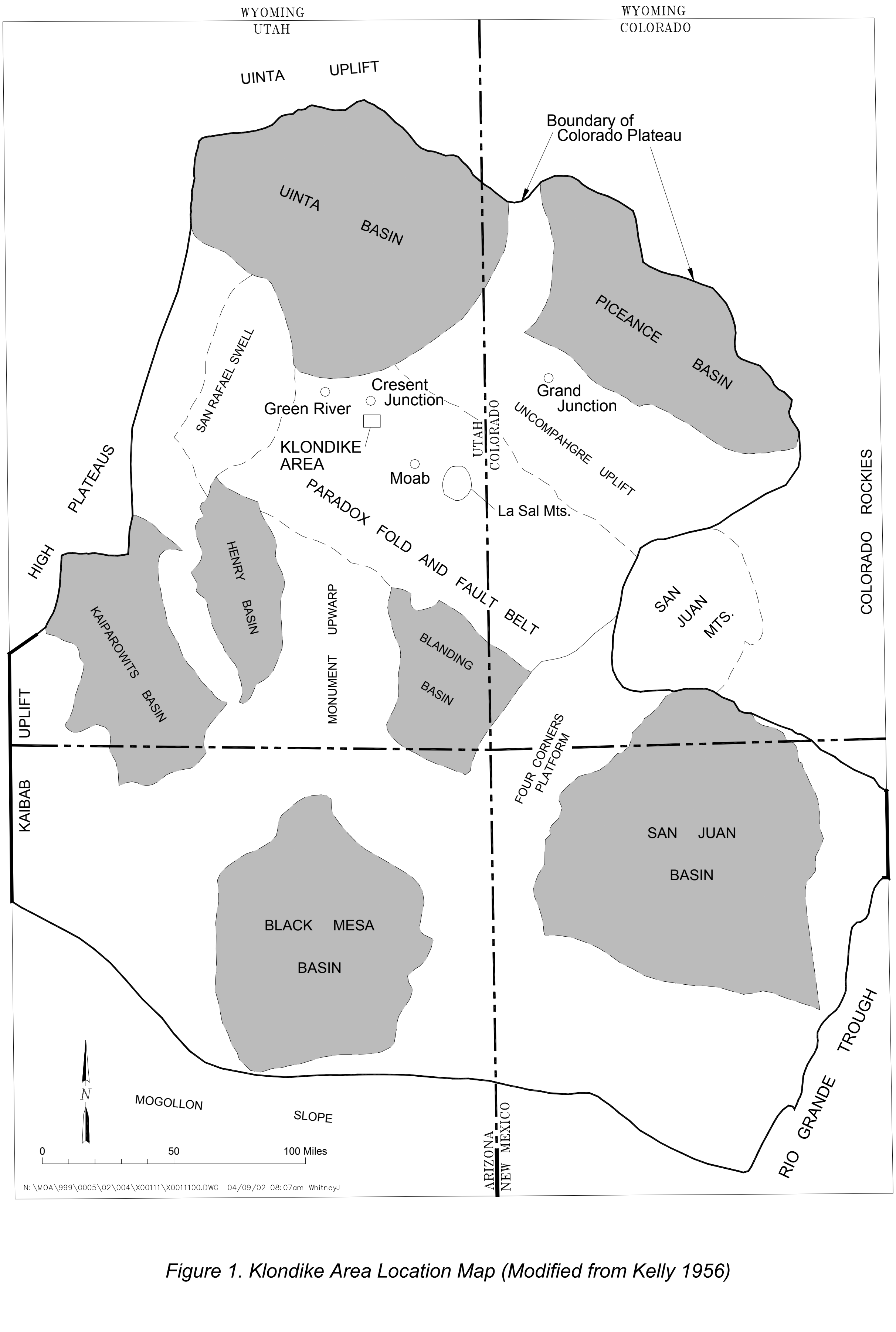

Figure 1. Klondike Area Location Map (Modified from Kelly 1956)

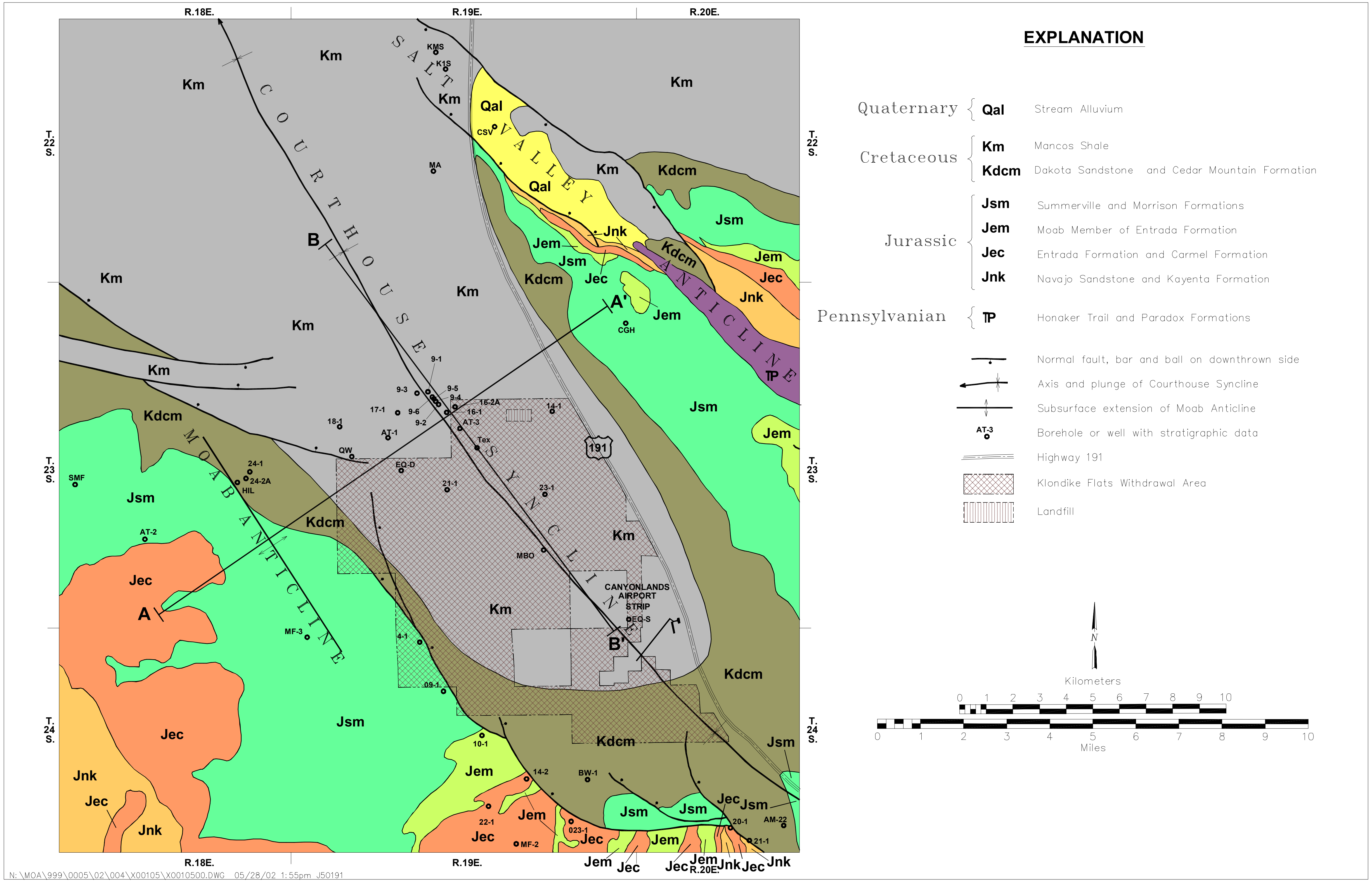

Figure 2. Generalized Geologic Map of the Klondike Area (after Doelling, 2001). A–A′ and B–B′ are Locations of Cross Sections in Figures 4 and 5

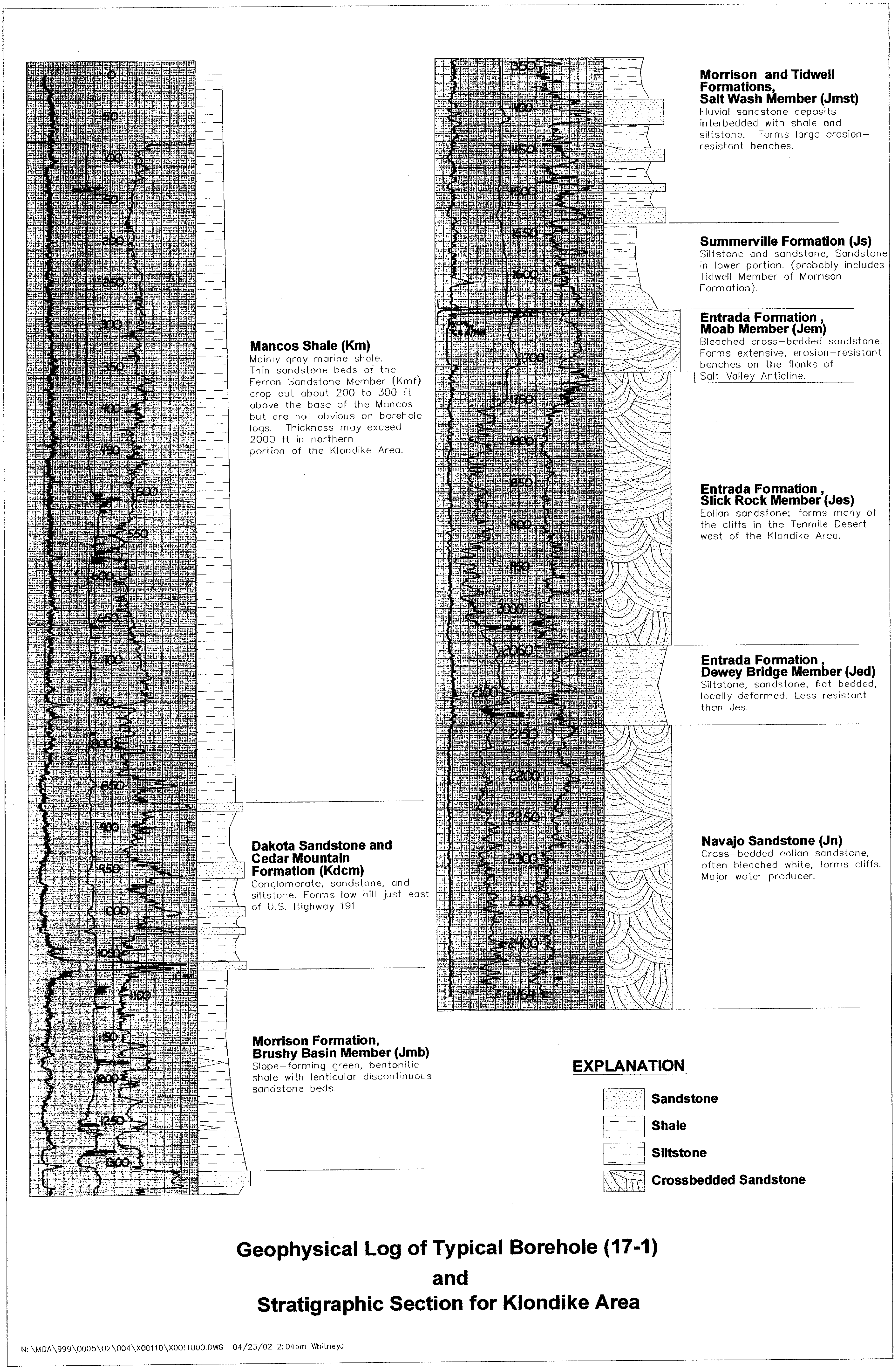

Figure 3. Example of Geophysical Log Used in Interpretations (geophysical data are from the American Heritage Center)
See Well Location on Figures 2 and 4

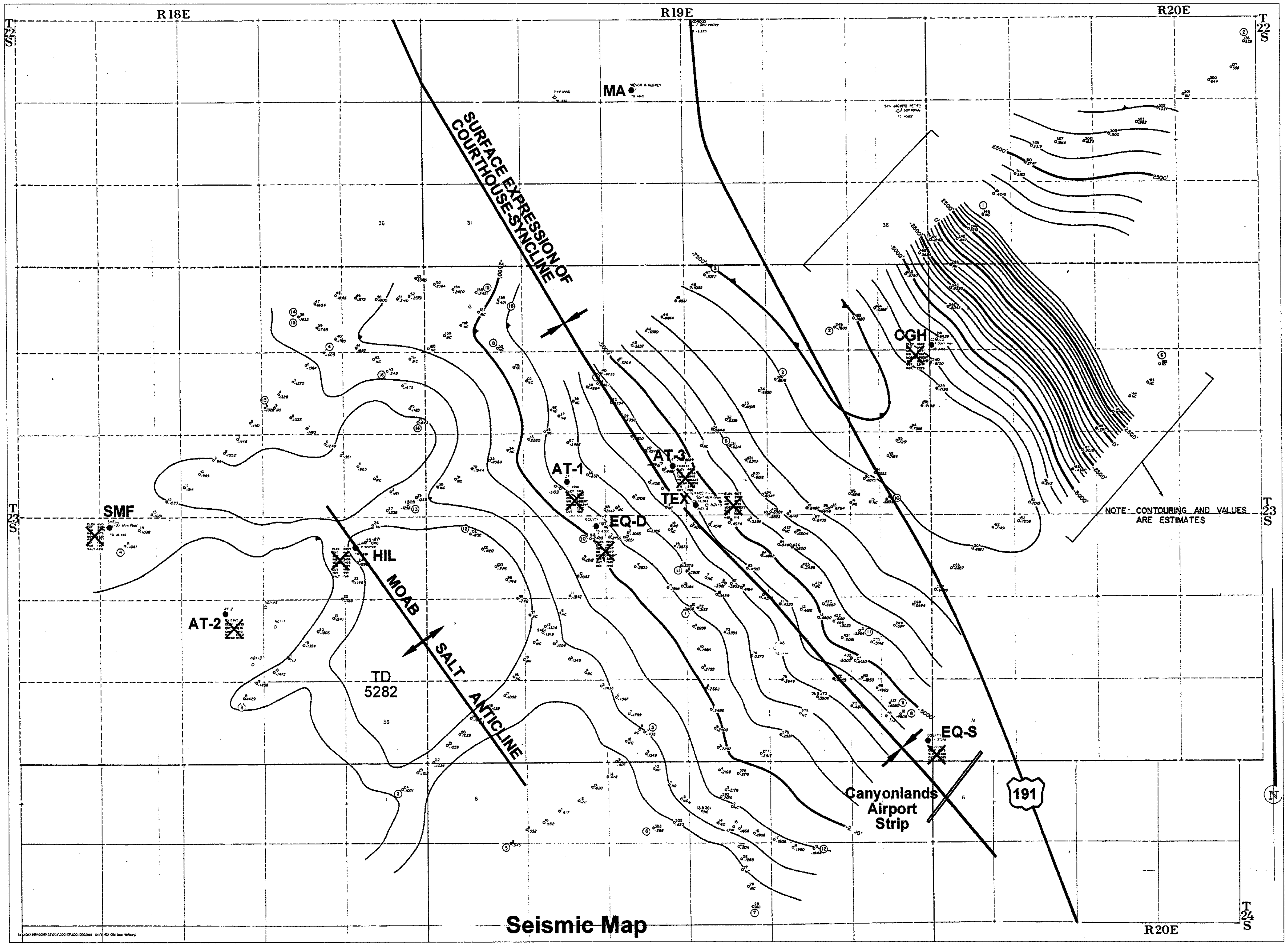

Figure 4. Structural Contour Map of the Paradox Formation Salt and Location of Seismic Lines (seismic data from the American Heritage Center)

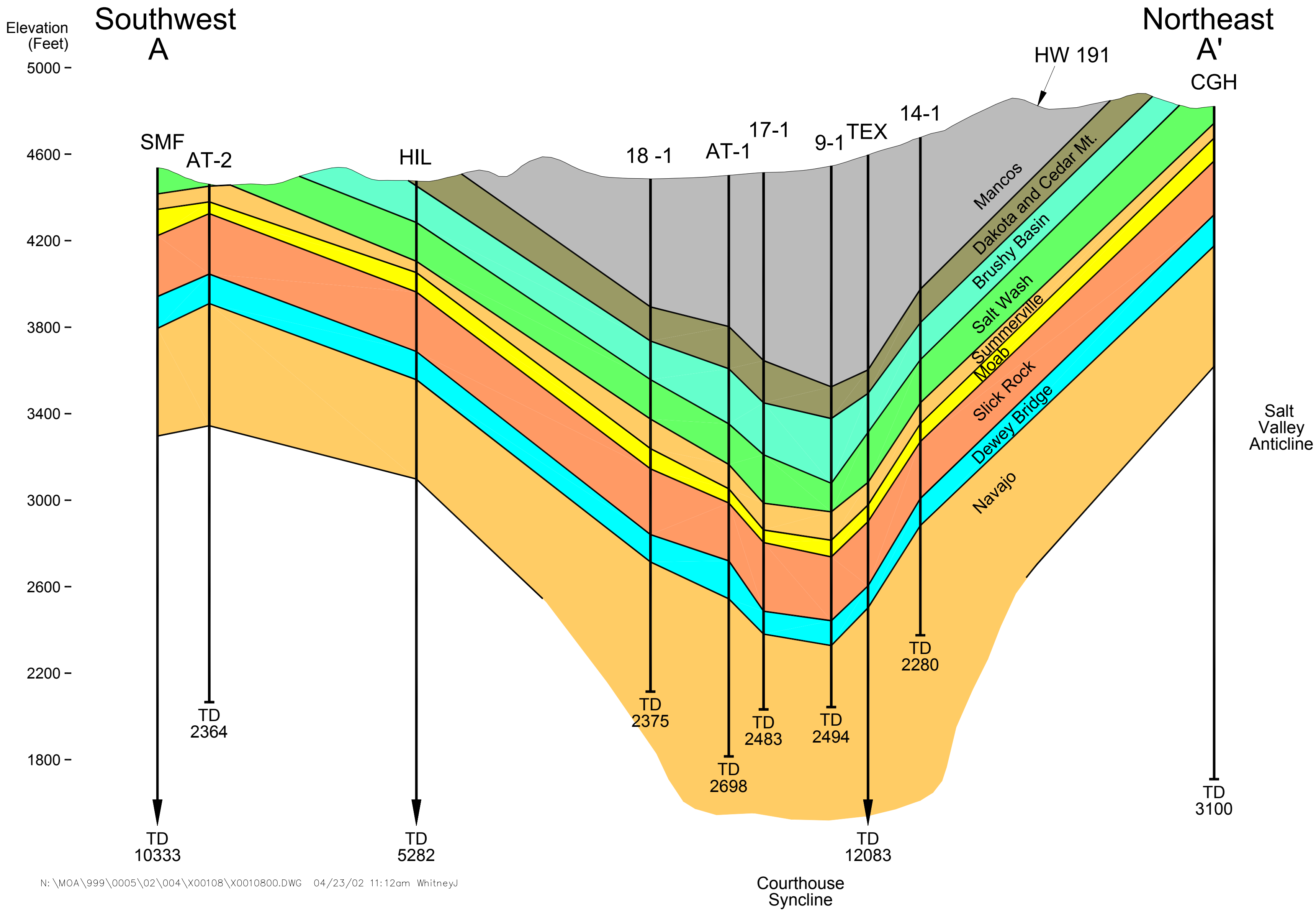

Figure 5. Cross-Section A–A′ Transverse to the Courthouse Syncline (data for this cross section are from the American Heritage Center and well files at the Utah Division of Oil, Gas, and Mining). Location of cross section shown on Figure 2. TD = Total Depth (feet)

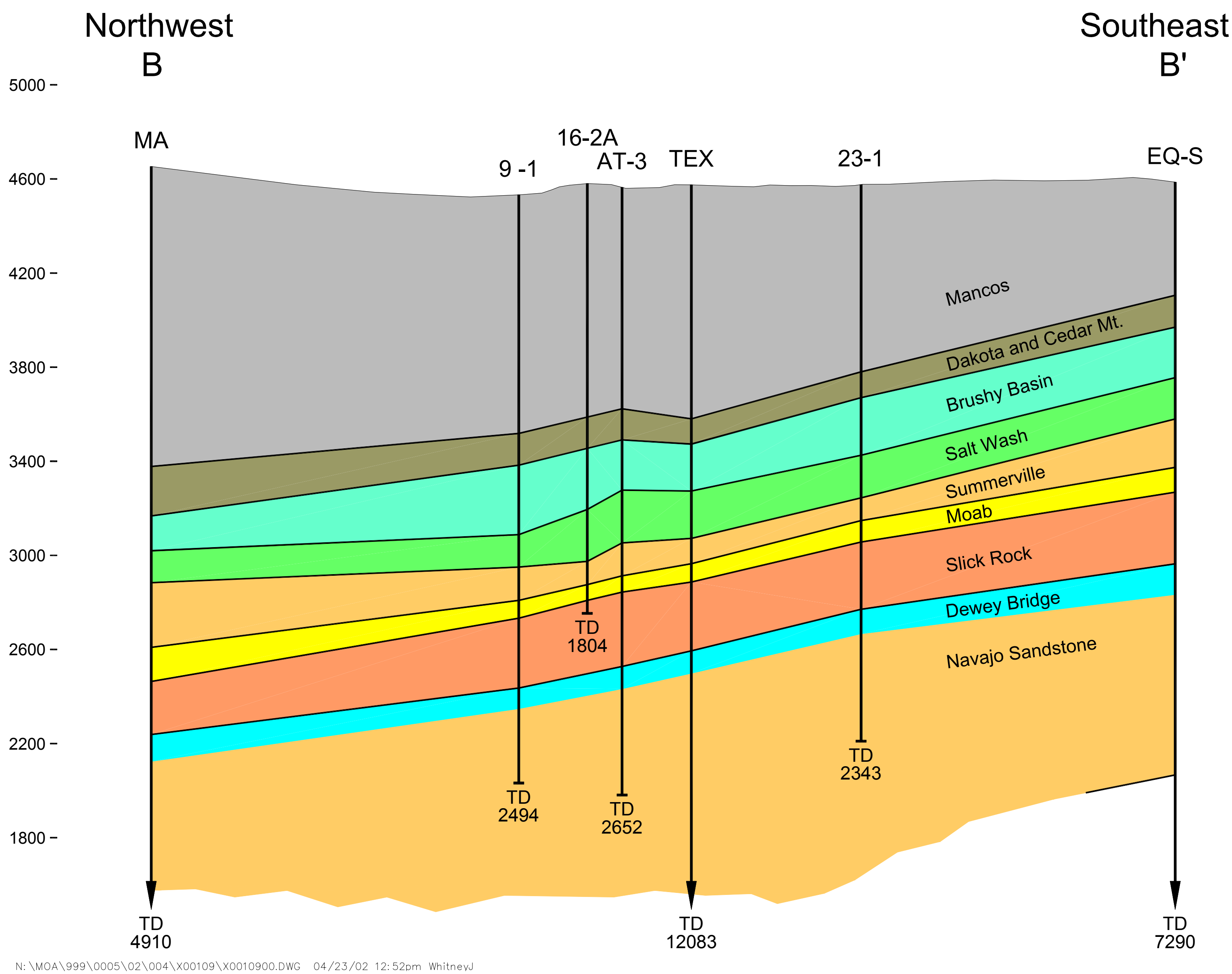

Figure 6. Cross-Section B–B′ Longitudinal to the Courthouse Syncline (data for this cross section are from the American Heritage Center and well files at the Utah Division of Oil, Gas, and Mining). Location of cross section shown on Figure 2. TD = Total Depth (feet)

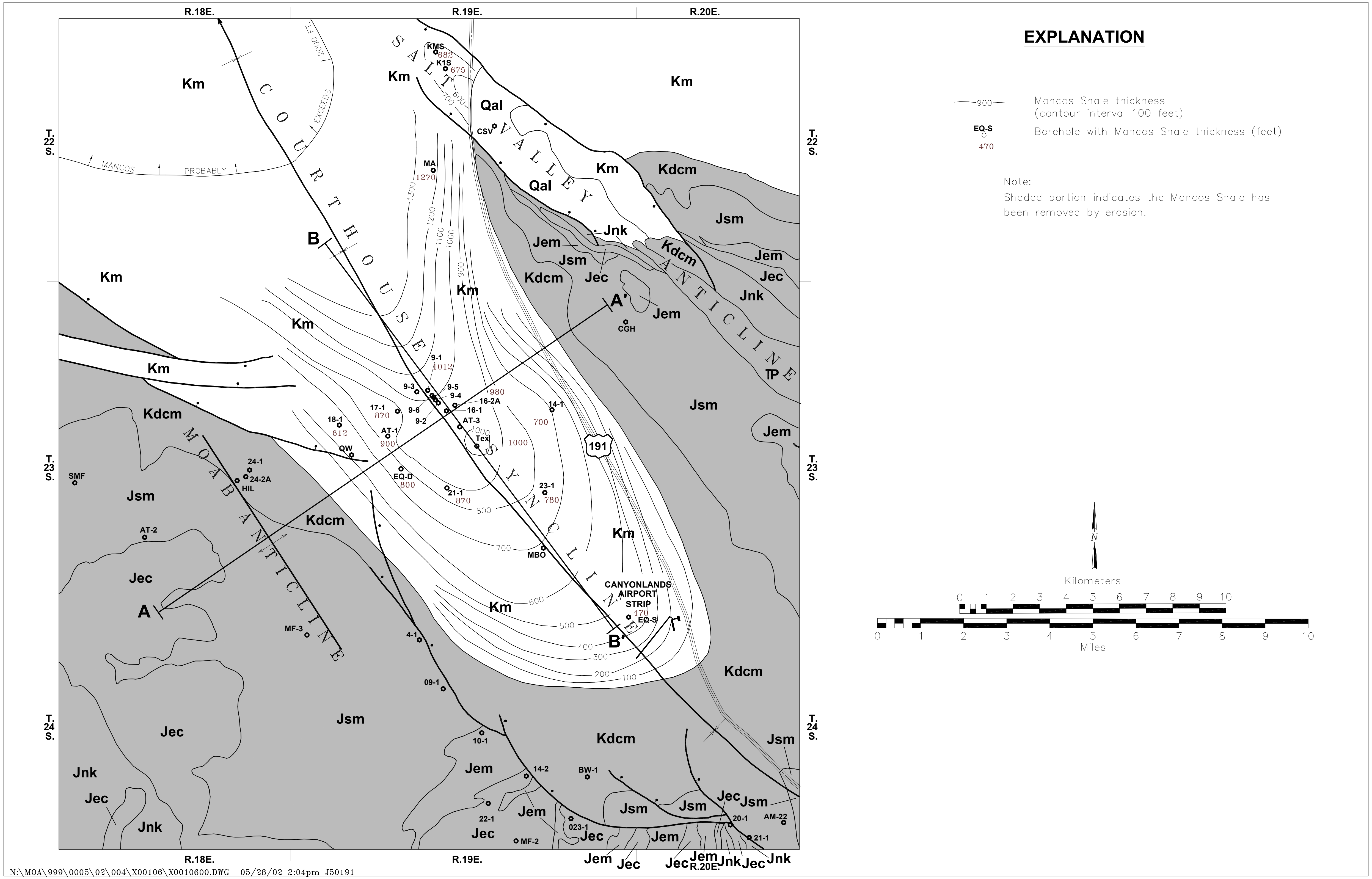

Figure 7. Isopach of Mancos Shale (data for this cross section from the American Heritage Center and well files at the Utah Division of Oil, Gas, and Mining)

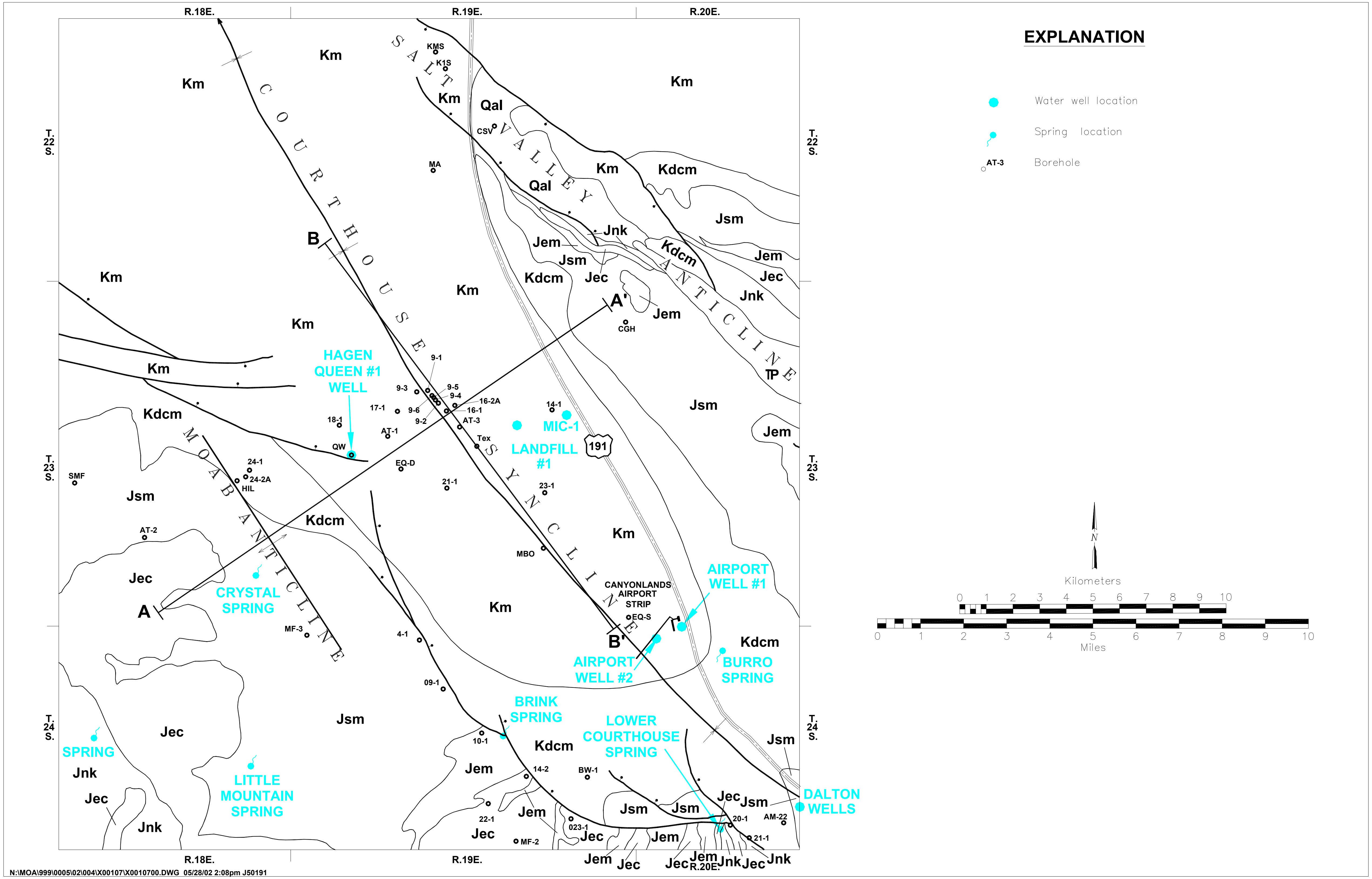

Figure 8. Location of Springs and Water Wells

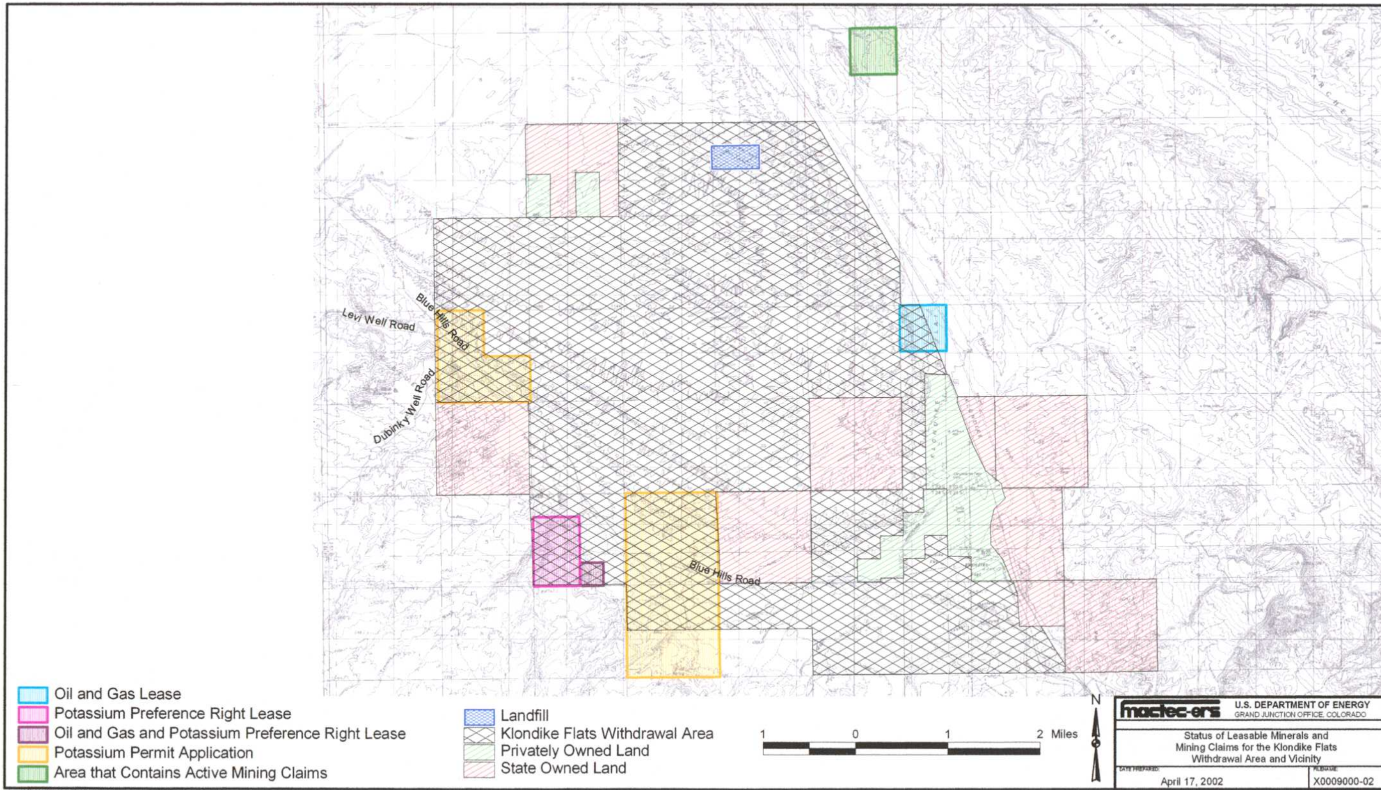

Figure 9. Land Status Map